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Pilot-scale synthesis of type X zeolites from coal fly ash

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Abstract

The development of new materials from different waste is one of the biggest areas of technological advancement worldwide, which has grown considerably in recent years. Associated with this is the importance of developing these materials at higher levels of production, so the technology is not only developed, but also disseminated on the global market. In view of this, the development of pilot plants for the production of materials on larger scales is extremely important, as in addition to ensuring the scalability of the material, it serves as a contribution for methodological tests before they are produced on an industrial scale. Several studies have been carried out regarding the synthesis of zeolites from fly ash obtained from coal power plant, which is a promising raw material for obtaining the product. Related to zeolites, mainly type X, studies demonstrate their great potential as an adsorbent in CO_2 capture, for example, and therefore, this work aimed to synthesize zeolite type X from the fly ash in a pilot plant installed at SATC - Beneficent Association of the Santa Catarina Coal Industry, located in Criciúma, Santa Catarina-Brazil. The methodology used was fusion followed by hydrothermal reaction, and the zeolite obtained (XFF-PP1) showed good mineralogical formation, with phases typical of type X zeolites, good chemical composition, surface area of 713.82 m^2 and adsorption capacity of 2.30 mmol/g of CO_2, thus validating the process on a pilot scale.

Keywords: Waste; Zeolites; Scalability; CO_2 capture.

1. Introduction

The use of waste associated with technological development makes zeolites a highly studied product with high added value. Consisting mainly of silicon and aluminum, their synthesis can come from ash generated from the coal power plants [1]. The porous structure of the material means that it can be applied in different areas, one of which is CO_2 capture. Studies indicate that type X zeolites have good adsorption capabilities when used to capture CO_2 in high concentrations, making this an attractive material from a technological point of view [2,3].

Furthermore, an important factor to be considered is that the cost of producing zeolites from coal ash is around 40% cheaper than imported zeolites, which also ends up contributing to their development on a larger scale, in addition to enabling the country is figuring out how to develop technology for manufacturing zeolites on a large scale from coal ash.

The impacts in the socio-environmental field are also relevant. The use of zeolites as an adsorbent in relation to CO_2 capture, contributes to demonstrating the efficiency in the capture process using a high capacity and low cost adsorbent, not restricted only to solid fuel burning processes, as it can also be applied to liquids and gases such as ethanol, natural gas, catalytic cracking from the petroleum industry, etc [4,5].

Therefore, the objective of this work is to present results of the characterization of a zeolite synthesized from coal fly ash, in a pilot plant installed at SATC - Beneficent Association of the Santa Catarina Coal Industry, located in Criciúma, Santa Catarina, Brazil.

2. Methodology

The zeolite synthesis was carried out in one of the reactors, 500 L, as Figure 1.

In general, different steps are carried out to obtain the material, with the method used in the system being fusion followed by a hydrothermal reaction. The synthesis consists of:

Fig.1. Zeolite Pilot Plant.

Preparation of raw materials (1): Consists of grinding and fusing sodium hydroxide with fly ash obtained from the coal power plant, carried out at the Jorge Lacerda Thermoelectric Plant – Diamante Energia.

Aging stage (2): Referring to the addition of raw materials prepared in Stage 1 into a reactor containing a sodium aluminate solution with pre-established volume and concentrations. In this step, the material is left to stir at room temperature. After this, the solution is heated and a new synthesis stage begins.

Hydrothermal reaction (3): In this stage the material is heated for approximately 12 hours, at a temperature around 95°C. After this period, the reactor heating is stopped and the material is poured into a filter press.

Filtration, washing and drying (4): Once in the filter press, the material is filtered and washed with water until it reaches pH <10. After these processes, the material is then poured into trays and dried for 2 hours at a temperature of 105°C.

Once the drying process is complete, the material is sent for characterization, with analyzes of mineralogical composition, chemical composition, textural properties and CO_2 adsorption capacity carried out.

3. Results and discussions

The characterization of the ash used as raw material for the synthesis of zeolite was carried out. Figure 2 shows the mineralogical composition of the material, with quartz, mullite and hematite as phases that refer to the presence mainly of silicon, aluminum and iron oxides in the material, which were confirmed from the analysis of the chemical composition of the material. gray, shown in Table 1.

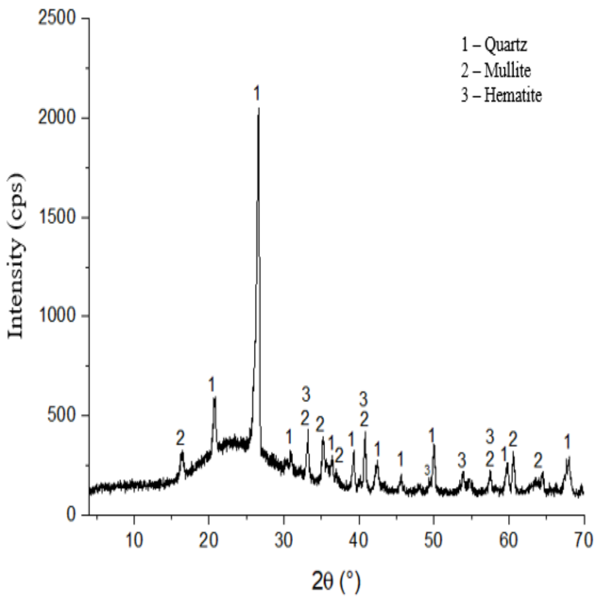

Fig.2. Mineralogical composition of ash.

Table 1. Chemical composition of ash.

Elements	Fly Ash (%)
SiO_2	59,77
Al_2O_3	24,24
Fe_2O_3	6,62
K_2O	3,88
CaO	1,74
Others (<1,5)	2,49
LOI	**1,70**
Total	**100**

As for the material produced, an identification code was created for it, which is XFF-PP1 (Zeólite X, Fusion, Pilot Plant 1). Figure 3 presents the diffractogram referring to the mineralogical composition of the material, which is compared with a commercial zeolite type 13X.

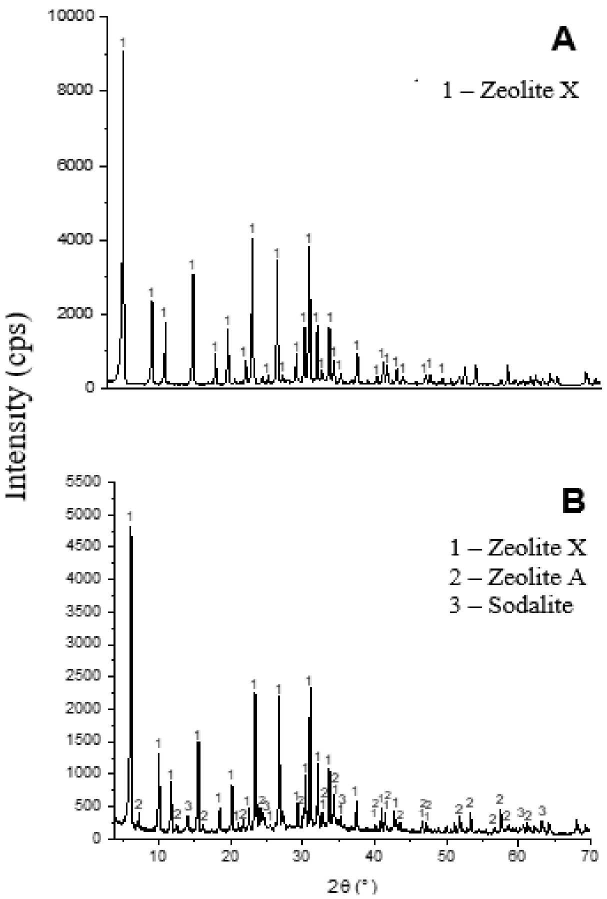

Fig.3. Mineralogical composition of zeolites where A (Commercial) and B (XFF-PP1).

As can be seen, the characteristic peaks of type X zeolite are observed in the presence of other typical phases that is formed when coal ash is applied as raw material [3,5].

Regarding the chemical composition of the product (Table 2), making a comparison with commercial zeolite, it is possible to observe that the majority elements, as expected, are SiO_2, Al_2O_3 and Na_2O and that the ratio between SiO_2/Al_2O_3 is 2. Furthermore, the presence of sodium, iron and other elements above commercial zeolite is observed in greater quantities in the XFF-PP1 zeolite, a fact resulting from the use of a residue as raw material.

Table 2. Chemical composition of zeolite XFF-PP1 and Commercial type 13X.

Elements	XFF-PP1	Commercial (%)
SiO_2	31,42	37,12
Al_2O_3	20,55	22,49
Na_2O	14,27	12,17
Fe_2O_3	4,1	0,05
Others (<1,5)	3,21	0,62
Subtotal	73,55	72,45
LOI	26,44	27,12
Total	100	100
SiO_2/Al_2O_3	2	2

Related to the material's surface area, diameter and pore volume, the results indicated that the material has 713.82 m^2.

With this, after evaluating the main characteristics associated with the formation of type X on a pilot scale, the material's adsorption capacity test was then carried out, with the material produced showing a capacity of 2.30 mmol/g of CO_2.

4. Conclusion

It was possible to conclude from the results presented in this work that it is possible to synthesize, on a pilot scale, type X zeolites from fly ash from the coal power plant.

The characterizations of the material produced in relation to a commercial zeolite proved to be satisfactory, since it was possible to confirm from the mineralogical composition of the material the presence of the typical phases of zeolite type X from coal fly ash.

The textural property test served as a complement to the characterization of the material since, as it is an adsorbent, it has a surface area, diameter and volume of pores that serve as parameters to delimit the application of the material in different areas.

With the test regarding the adsorption capacity of the XFF-PP1 zeolite, it was possible to observe that the material is a promising adsorbent for CO_2 capture, thus validating one of its possible segments in the market.

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